the tonal apparatus of the ear. It was further proved that a series of short and sharp sounds like those of a watchman's rattle, provided all extra accompanying sounds were fully damped, could be as rapid as 600 or more per second before producing an even tone. The corresponding parts of the ear leap into vibration at the first impulse, and as quickly subside. This makes possible a wide range of untonal sensations. If tone arises from continuous, even, and regular stimulation, noise arises from short, irregular and suddenly varying stimulation; and the two classes of sound pass into one another by insensible gradations. The complex noises, rustling, hissing, blowing, etc., can be reduced to noises as simple as those tested, differently combined, varied in quality, intensity and rapidity, and accompanied in differing degree by true tone. These experiments do not exclude the possibility of special organs for noise-hearing, but they seem to make their assumption, which is attended with difficulties, unnecessary.

Ein Kinesiæsthesiometer, nebst einigen Bemerkungen über den Muskelsinn. E. HITZIG. Neurol. Centralblatt, May 1 and 15, 1888.

The kinesiæsthesiometer, less formidable than its name might suggest, is a set of 17 wooden balls for testing "muscle-sense." The balls are about 7 cm. in diameter, and graded from 50 to 100 grs. by 10's, from 100 to 300 by 50's, and from 300 to 1000 by 100's. For use with the lower extremities, a stocking is provided with a pocket at the heel for the reception of the balls, the patient lying on his back during the experiment. The advantages of this device over others mentioned by the author consist in its easy and speedy application and in its portability. Previous measurements of the fineness of discrimination are discussed, and one tenth, the smallest difference for which this apparatus is adjusted, is taken as about the limit of sure discrimination with the upper extremities for normal subjects, and thus as an appropriate starting point for testing those whose sensibility is blunted by disease. For the lower extremities the limit is one tenth or more.

A large portion of the paper is taken up with a discussion of what is really measured in tests of this kind, and particularly of the hypothesis of a special central *Kraftsinn*. The author is not opposed to such an hypothesis—in fact, does not see how voluntary motion is to be explained without it—but at the same time does not believe that it is necessarily a conscious sensation, nor independent of the centripetal sensations from muscle, skin, and joint. He adds an interesting critique of arguments pro and con, together with three cases from which such a sense might hastily be deduced, but which on closer examination are inconclusive. In such experiments he considers one measures the sensations of movement in the most general meaning of the word, hence the name of his instrument.

Grundlinien zur Erforschung des Helligkeits- und Farbensinnes der Tiere. VITUS GRABER. Prag, Temsky; Leipzig, Freytag. 1884, pp. 332.

The question of the color-sense of animals has been put into a new stage of development by the admirable experimental work of Vitus Graber. His investigation has hardly received the attention which it deserves, and it seems worth while to give a summary of his results, although they are already four years old.

In studying the function of the eye in animals, it would seem to be self-evident that the color-sense ought to be sharply distinguished from the brightness-sense. If an animal is merely given the run of several different colored boxes, he has no means of knowing whether his experimenter wishes him to choose a resting place on the ground of color or of brightness; he may prefer a dark blue box to a bright red one, although with equal brightness, his choice would be for red rather than blue. It is absolutely necessary to eliminate the question of brightness before attacking the question of color, and this, strange as it may seem, has hitherto not usually been done. What is still stranger, both of the erroneous conclusions that are possible in the case have actually deen drawn.

The first experiments on the color-sense of animals were made by Paul Bert in 1869, on daphnids. These little animals strongly preferred the yellow-green to the other portions of the spectrum, and M. Bert had no hesitation in concluding that they did so on account of its greater brightness; he even infers, what is still worse, that "throughout the whole visual region, the difference of brightness of the different colored rays is the same for them as for us." On the other hand, Lubbock's experiments on bees, ants and wasps, though exceedingly painstaking in other respects, were not sufficiently controlled by other experiments on the brightness-sense of these little animals. Mereschkowsky (Compt. Rend. I, 93, p. 1160) distinguished between the two kinds of sensitiveness, but from the fact that certain low crustaceans did not react to differences of color, he inferred that they are not able to distinguish colors. Experiments of this kind, as Graber points out, can give only positive results, not negative ones. If the greater portion of the animals experimented upon leave the blue box for the red one (the brightness being equal), then the fact that they *prefer* red proves that they can *distinguish* red; if they distribute themselves equally, it is merely shown that they do not, under the given circumstances, prefer one color to the other, not that they are incapable of distinguishing between them.

Graber's experiments were conducted with very great care, and his conclusions are also, for the most part, unexceptionable. He experimented on about fifty different animals. He preferred to offer his animals the choice of two boxes only at a time; he rightly considered that to ask them to bear in mind and to choose between four different colors at once is to put too great a strain upon their mental powers. Each species was tested first for its preference in regard to brightness and darkness. Colored lights were obtained by means of glasses and solutions (fifty-eight in number), all carefully tested for their color by means of Zeiss' micro-spectroscope, and for their brightness by a Rumford photometer. On account of the difficulty of obtaining different colors of equal brightness, the animals were usually offered first a choice, say between a brighter red and a darker blue and then between a darker red and a brighter blue. If, as they often did, they chose the same color in both cases, this of course plainly showed a strong preference for that color, irrespective of brightness. The caterpillars of *Vanessa urticae,* for instance, chose a bright blue rather than a dark red chamber in the proportion of 196 to 66; but they also preferred a dark blue to a bright red one in the proportion of 193 to 81, in spite of the fact that in colorless chambers they preferred light to darkness in the ratio of ten to one.

Graber's results are extremely interesting. They establish beyond

doubt the existence of a very widely distributed color-sense among animals; of the fifty animals experimented upon, no less than forty showed strong color preferences. There is, of course, no reason to suppose that those which did not react to color differences are insensitive to color, but merely that they are indifferent to colored resting places; they include highly developed animals, as the cat, the guinea-pig, the rabbit, the dove, the hen, the parrot and the turtle. A sensitiveness to ultra-violet light, which Lubbock established for ants and daphnids, Graber finds to be very common—nearly all of the twenty animals which he examined in this respect exhibited it. The bullfinch (*Pyrrhula vulgaris*), for example, showed a preference coefficient of 2.5 for blue with ultra-violet over blue without ultra-violet. Chrysomela, which loved darkness, and had a strong preference for red over every other color, was absolutely indifferent (190 : 194) to red and black, while it distinguished between white with and without ultra-violet with the instances 72 and 154 respectively. In general, animals which love the dark are red lovers, and those which love the light are blue lovers, but this is not a rule without exceptions, and Graber considers that no adequate explanation can at present be given of it. The strength of the preference between red and blue is greater than that between any two colors that are nearer together in the spectrum.

But the most interesting results were obtained with eyeless and blinded animals. The common worm was known before to be sensitive to light, but it was believed by Hofmeister and Darwin that it was sensitive only at the cerebral end. Graber obtained for it a preference of five to one for black over white when whole, and of three to one when, in order to be sure of getting the right end, 7 mm. in length had been cut off from both ends. In this amputated condition its preference for red over blue (3 to 1) was nearly as great as when uninjured. The animals selected for blinding were the triton and the cockroach. In the case of the former, the eyes were removed, the holes filled up with wax and the whole head covered with a thick cap of the same material. (In this condition, and without food, they lived and remained active for months.) Of 2102 trials, there were 674 cases of seeking the bright compartment, and 1428 of seeking the dark one; the preference for green over blue was 5 to 3, for red over green it was 2 to 1, and for white without over white with ultra-violet it was 5 to 2. Control-experiments were made in this case as in others, to exclude the effects of heat, though there was no sensible difference of temperature between the two compartments. The cockroach had the antennae removed and the head covered with a thick coating of black wax. It gave a preference coefficient of 2.3 for black over white, and of 1.7 for red over blue; the corresponding numbers for the normal animal were 7 and 5. It could even distinguish plainly between rather slight differences of brightness. Herr Graber admits that though he was already accustomed to surprises, these last results threw him into a state of actual excitement. He is of the opinion that the animal is induced to go into one compartment rather than another by means of a special skin sensation, and not of a mere change in the carbonic acid production, though that is known to be affected by a difference in color of light; the motion is so rapid and energetic that he thinks there is not time for it to be caused by a feeling of lack of breath. Moreover, such low animals as snails, when their eyes have been destroyed, quickly

develop new ones out of depressions in the skin. One is reminded of the experiments of Fontan, in which a hypnotic subject readily sorted with his hands colored wools which it was impossible for him to see, though these are, of course, far too extraordinary to be accepted from a single instance.

Several questions which have been hotly discussed would seem to be definitely disposed of by Graber's experiments. (*a*) It is plainly established that animals have a color sense. Grant Allen affirmed that it is very rarely that animals react to differences of color, which shows, as our author remarks, the danger of investigating nature after a purely speculative fashion. (*b*) Do colors look the same to animals as to us? To those which are sensitive to ultra-violet, and to those, if there are such, which are insensitive to red, they evidently do not; white, and every other color which is not of spectral purity, must look different to them. As regards others, there was never any ground for discussing the question; there is no possibility of answering it one way or the other. (*c*) Magnus and others have said that certain animals which have no cones in the retina must be for that reason insensitive to colors. It is now plain that the color effect must be due not to any particular morphological structure, but to the presence of certain chemical substances decomposable by light. (*d*) The existence of colored flowers and fruits is certainly not essential to the development of a color sense. It is not even true that flower-loving animals have a more highly developed color-sense than others; the flea which infests the dog reacts to much finer color-differences than the bee. (*e*) The theory that the men of Homer's time had any difficulty in distinguishing colors will have received, it is to be hoped, its deathblow.

We have only two criticisms to make upon Graber's work. He does not give sufficient importance to the fact that the choice which his animals exhibit is choice of a *place of abode*, and that they might have different color-preferences for small objects. He does not seem to have offered his animals the choice between green and blue without ultra-violet: with blue with ultra-violet and green, they gave very marked reactions. C. L. F.

Some Observations on the Mental Powers of Spiders. GEORGE W. and ELIZABETH G. PACKHAM. pp. 36. Reprinted from the Journal of Morphology, Vol. I, No. 2, December, 1887.

These entertaining experiments upon the mental powers of spiders extended to the sense of smell, their hearing, maternal emotions, sight, color-sense, feigning death, and their mistakes. The experiments on the sense of smell were conducted as follows. A glass rod dipped in an odorous liquid was held near the insect, and its motions observed. These experiments were checked by offering the clean rod under the same circumstances. The odors used were essential oils, cologne, and other such perfumes. In 220 experiments on a number of species, but three species were found that did not respond. The responses were "by various movements of legs, palpi, and abdomen, by shaking their web, by running away, by seizing the rod and binding it up with web as they would an insect . . . . by approaching the rod with the first legs and palpi held erect." To loud noises most spiders gave no sign, though one, when on the finger, jumped when "bang" was shouted, and erected its head